From Promising to Practical: How Standards Help Bring New Materials to the Market

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INTRODUCTION

Let us make a bold statement to begin with. Based upon numerous conversations with individuals in industry and elsewhere, it is our conclusion that "For new materials, standards are not a barrier to trade." In this paper, we use the word standard generic in the narrow context of material property test method standards. We do not consider product specification standards. Experience suggests that neither the existence nor the lack of materials test standards enable one country to influence sales of new materials or impedes trade in some way. Indeed, standards sometimes lag behind the introduction of new materials to the marketplace. What then, is the importance of standards?

We recognize several key advantages in having standards. The road for a new material from the research laboratory to commercial application may be smoothed by standards. As a new, improved material is introduced to the marketplace as an alternative to similar materials, data generated by standard methods can facilitate the acceptance of the new material. More radical changes occur when innovative materials and products are introduced for which there are neither precedents nor standards. The path from the research laboratory to the commercial sector is often strewn with pitfalls of data inconsistency that cause confusion, inefficiency, and added costs. Recognition of the problem usually occurs when an innovative material has matured to the point that multiple sources or users are involved. With recognition of the problem comes a commitment to standardization, but the standardization process itself can be time consuming and frustrating and could even delay commercialization.

The ability to make common measurements on the same materials at various places on the globe is critical to world commerce due to the increasing globalization of markets. We must have consensus based standards and specifications. Both users and suppliers of materials around the world need the assurance that the property of the material obtained in one country was obtained in the same way as in another. For new materials in emerging markets such standards are particularly important. In this paper, we will attempt to provide specific examples where standards really made a difference for the entry of new materials into the marketplace.

CERAMICS AS AN EXAMPLE

We intend to use "ceramics" as the broad class of materials from which examples of standards relating to market development will be extracted. Standards are important for other materials as well, but the examples that we will show are wide-ranging enough in character that they make a case for themselves.

It important at the outset to define what we mean by ceramics, because the first thing that people think of when the word is mentioned is usually bathroom fixtures, dinnerware, or tiles. Ceramics are much more than that. Ceramics as a class of materials is extensive, (in some respects, any inorganic, non-metal) and they are present in many different applications (Figure 1). Ceramics are used in these myriad of applications because of their unique structural, electronic, magnetic, and optical properties.

STANDARDS LEAD TO COST SAVINGS

In most applications, the ability to measure the critical material properties is extremely important for the commercialization of these materials. One of the problems with ceramics—well, many of you could figure out—is that they are brittle. So whenever we use them, whether in structural applications such as engine components, or elsewhere, it is important for the designer to be able to predict the safe, reliable operation of a component over a long period of time. So for anyone developing a new ceramic material, being able to accurately measure its strength is an important consideration.

The easiest way to test the strength of a ceramic is to bend it in what is called a flexural test (Figure 2). The rectangular prismatic specimen is cut from ceramic plates or components. This type of test is the bread and butter method of the ceramics industry and is much simpler than traditional tensile strength tests with dog bone specimens. Before the development of harmonized measurement procedures, everything about the flexure test could change from one laboratory to the next. So material suppliers would test their products in different ways, giving rise to the reporting of different properties, because they were, in fact, using a different kind of test. In addition, one of the significant costs in testing of

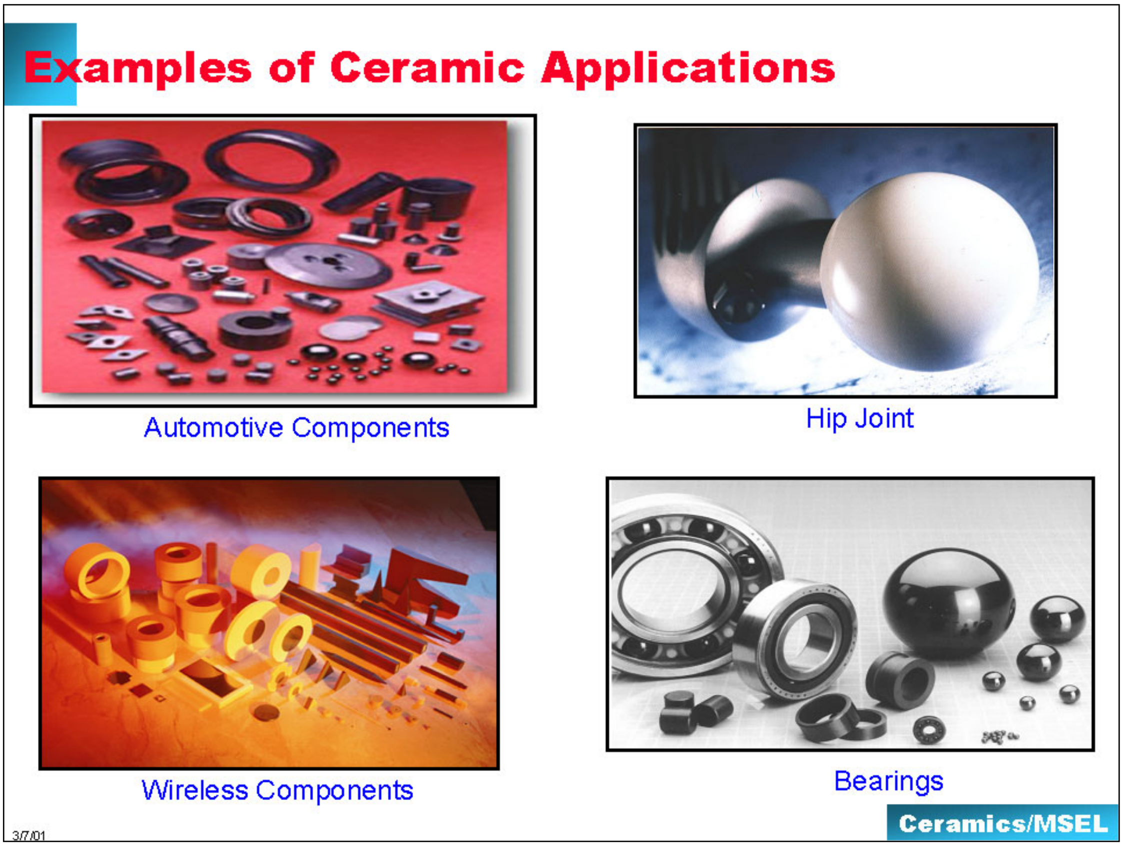

Fig. 1. Examples of New Ceramics.

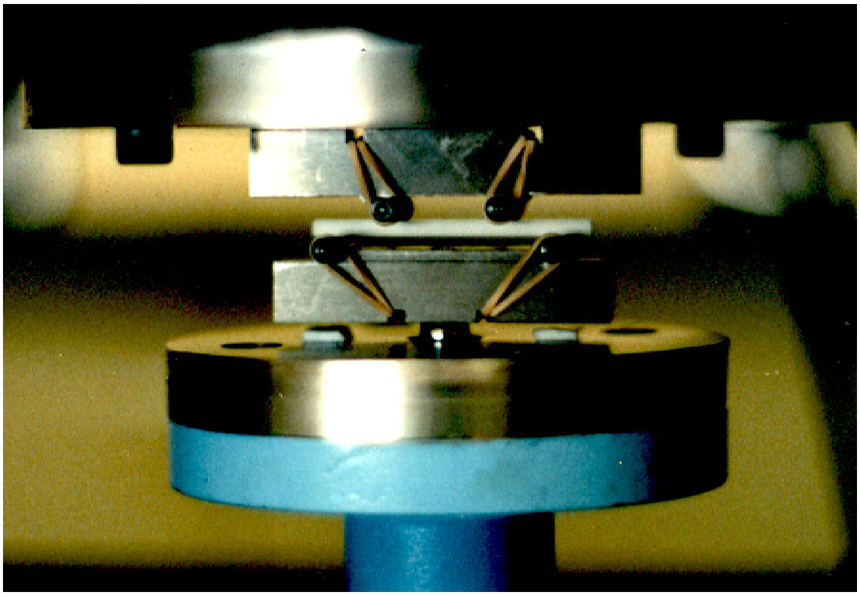

Fig. 2. Flexural testing is the most common method to evaluate ceramic strength. A simple beam specimen (white in the photo) is loaded in a four-point bend fixture until fracture occurs. The standardization of the specimen size and preparation, and the fixture size and type, has led to dramatic improvement in data quality and major cost savings.

ceramics is that associated with machining a specimen. Because of their hardness and susceptibility to damage, machining costs for ceramics are significant. Prior to the development of standards, a typical specimen cost in the range of \$20 to \$33 in today's dollars. With the development of the American Society for Testing and Materials (ASTM) flexural test standard, the cost of those tests dropped to \$8 to \$10. Why? Because now standard fixturing could be employed, and machine shops knew that they Ire always going to make exactly the same specimen for everybody, and this allowed the test costs to drop precipitously, resulting in savings of something like \$800,000 to \$1.5 M a year.

Savings benefits accrued in other ways. Flexure strength testing was often performed for quality control purposes. A producer or user repeatedly tested sample sets of specimens from new batches during the material or product development phase. Prior to standardization, it was recognized that the myriad of methods then in use were not optimized and were faulty. Nevertheless, it was rationalized that the data was good enough for comparative purposes. While this attitude was probably adequate for testing within a single laboratory, the limitations were quickly felt when data was exchanged between multiple producers and users. Data discrepancies led to confusion and even distrust. Furthermore, rudimentary quality control or materials development data often did not meet the more stringent requirements for design or materials specification data. This often led to costly, duplicative testing. The adoption of a simple, technically rigorous, flexural strength standard method solved the problem. Now almost everyone tests the same way. Data collected for quality control purposes is immediately acceptable for the most stringent design applications and the costs of redundant testing have been eliminated. Intangible costs of doubt and distrust have also been eliminated by standardization.

STANDARDS SPEED ACCEPTANCE BY REGULATORY AGENCIES

With aging populations, many of us are going to need replacements for various parts. Biomaterials are a rapidly growing market segment, and artificial hips are one of the most prevalent uses of such materials. At present, most of the balls of such hip replacements are made of metal. But if one wants to replace hips in younger individuals, and leave them in for longer periods of time, then we must look for materials that are more inert, harder, and have better biocompatibility. That's where the ceramic material comes in (Figure 1). However, the use of any new materials for such applications must have the approval of the Federal Drug Administration (FDA). The FDA would like to see standards and specifications in place to enable them to more rapidly certify new materials. Although the FDA has the authority to write regulatory standards, they now rely on consensus standards developed in both national and international venues. Standards for biomaterials have been developed through ASTM, originally in the committee on advanced ceramics, C-28, who wrote the standards for basic material properties, namely strength, hardness, fracture toughness. Committee F-04 specifically dealing with medical materials and devices then used these standards to develop more detailed implant material specifications.

STANDARDS FACILITATE PURCHASING

One especially relevant example of the importance of new materials to modern technology, and of where standards can be influential, is the cellular telephone, and wireless communication in general. Without going into detail, we can state unequivocally that wireless communication would not exist today were it not for the unique electrical properties of key ceramic components. The development of these new materials for the wireless industry provides a good illustration how lack of standards can directly affect commerce in new materials. The following examples are particularly interesting because they are paraphrased from comments made by one of the leading manufacturers of wireless materials in this country:

- One problem with the lack of standards is that one company can promote its material over another, when in fact the only difference between the two materials is the fact that their properties Ire measured in two different ways. One sees apparent conflict; the buyer is not quite sure which is the right property of the material.
- Another important issue is the potential confusion in interpreting data. If one isn't sure how the particular property was measured, then there is clearly a problem in understanding what that property is.
- Thirdly, two vendors may supply a different product even though the material was ordered to the same specification.

All of the above conditions lead to the overall problem that customers may have to qualify each of its vendor's particular products.

WHEN ARE STANDARDS NEEDED IN THE DEVELOPMENT PROCESS

Finally, we want to touch on the issue of timing in the development of standards relative to the application of new materials. When a new material is developed, and if there is only one company manufacturing it for a particular application, specifications can result from a private agreement between the manufacturer and the end user. At this stage it is relatively easy to have this kind of communication. As the material matures, however, more manufacturers of ostensibly the same material appear, and there are more end-users that find the material attractive. At this point some kind of standard becomes important, because it defines the way that the critical properties of the material should be measured.

An example of such timing can be shown in the development of ceramic bearings. Because they can operate in inert environments without the need for lubrication, ceramic bearings are becoming more and more prevalent in applications such as high-speed machine tools, turbo pump motors, food processing equipment, and even dental drills. Initially, however, before the markets for such bearings developed, only a relatively few materials (essentially different varieties of silicon nitride) were available. Individual manufacturers agreed with individual users on the properties that Ire needed. As the market matured and users groomed second sources, these informal arrangements were no longer sufficient. A new effort has now been developed within ASTM to write formal standard specifications for these materials. In this instance the process will be expedited by the existence of a battery of generic ceramic test method standards, already on the books, that are eminently suitable for the bearing industry.

In contrast to the bearing case, radical new materials and applications may develop for which there are no standards. New materials often require new methods and frequently a variety of expedient test methods arise. No one wants to spend a lot of time and effort on refining test procedures when the material, product, or the market is unproven. Eventually it becomes apparent that the multiple methods are creating confusion and doubt. It seems obvious that a consensus, standardized method is needed, but by then, large internal company databases have been compiled. There may be a genuine reluctance to have such rendered obsolete. The recognition that standardization is needed usually occurs when a material, or product has reached the point that multiple venders or users wish to compare data with confidence and minimum fuss. At this point the interested parties may come together in consortia or in formal standards development organizations such as ASTM, and the process of forging a consensus standard begins. Once standardization is accomplished, the impediments of data incompatibility, data distrust, and duplicative testing are usually eliminated and commercialization proceeds more smoothly. We will not venture far done the path of describing how standards are created, but I make two generalizations. Experience suggests that the sounder the technical basis of a method, the easier it is to achieve agreement and the more the prestandization groundwork that has been accomplished, the faster and less contentious is the formal standardization process.

MATERIALS PRESTANDARDIZATION RESEARCH

We can define prestandardization research as being the collective activities of a group of laboratories to establish a measurement technique and agree on a uniform procedure for carrying it out. Prestandardization research is often conducted by leading national institutes such as NIST, NPL, and BAM. One organization that promotes such collaborative work is the Versailles Project on Advanced Materials and Standards (VAMAS).

VAMAS was formed in 1982 as one of 18 such cooperative projects, at the economic summit in Versailles, hence the name. The mission of VAMAS is to support world trade in products dependent on advanced materials technologies by providing the technical basis for harmonized measurements, testing, specifications, and standards. VAMAS promotes collaboration among the outstanding materials laboratories throughout the world, bringing together experts in many materials fields. VAMAS is governed by a steering committee composed of the signatories of the agreement, plus the European Commission. This steering committee is currently chaired by the U.S., through NIST. However, researchers from many other countries participate in the work of VAMAS.

VAMAS has formal linkages to both ISO and IEC, and perhaps of equal importance, the individuals who participate in VAMAS are typically also participating in their national standards bodies and in international standards development. These individuals see each other frequently, work together, and ultimately develop a mutual trust, which facilitates the development of standards on an international basis.

There are now 18 technical working areas in VAMAS, Table 1 addressing many different aspects of materials. Table 2 illustrates how, in the area of ceramics, VAMAS work has led to national, regional, and international standards.

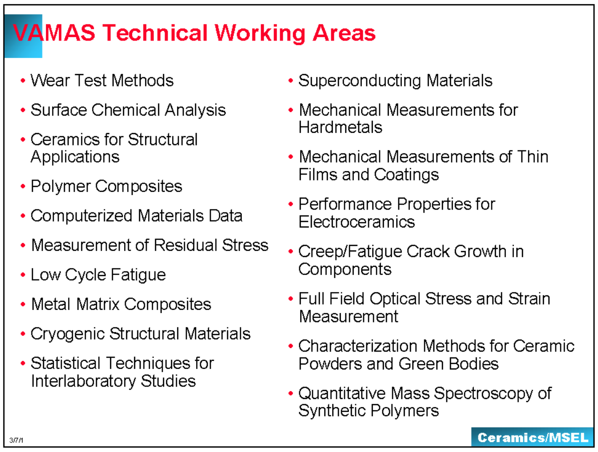

Table 1

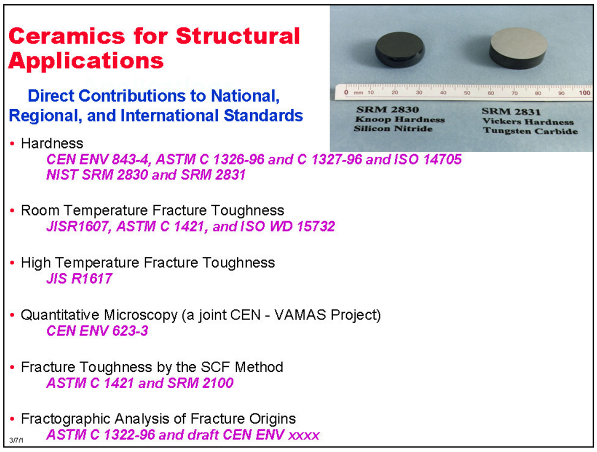

Table 2

SUMMARY

In summary, standards are important and facilitate commerce in new materials for a number of reasons. First, they help produce reproducible consistent data. They lead to better specifications for materials and so the buyer, the end-user for whom these materials are important, knowing the true properties of that material, can select the material which best suits his application,. Specifications for ceramics are not nearly as prevalent as those for metals, but they are rapidly emerging. Standards, and the writing of measurement procedures, will lead to better specifications.

Thirdly, standards lead to harmonized performance characteristics, which in fact is what we are looking for. Further, for a new material, the existence of a standard immediately makes that material more credible, more Ill-known, and more likely to be selected for a particular application. Finally, standards can be educational tools, in that they can instruct the end-user even as to what the material looks like, and how it should behave.

So, we see a definite relationship between standards and the commercialization of new materials. The existence of standards promotes new materials, and paves the way for their introduction into the market-place. In addition the standard aids the end-user by providing the kind of data that is needed in order to put these new materials in place in a wider variety of applications.